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Diesel Retrofit for Village Power

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The Diesel Plant Retrofit Market

Current Conditions

- Thousands of diesel plants installed yearly world wide
- High cost of diesel operation, both in fuel and maintenance
- Continual drain on economy due to fuel purchase
- Environmental damage due to diesel fuel (pollution/spills)

System Inefficiencies

- Poor sizing of diesels compared to load
- Large manual content, staffing problems
- Spare parts availability and delivery
- Low reliability and maintainability



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Common forms of retrofitting

Five types of retrofitting options are seen as most likely:

- Type A:** Adjust diesel size or install a second diesel engine.
- Type B:** Add automatic controls to existing diesel plant.
- Type C:** Install batteries and a power converter to cover low load periods in evenings or during day.
- Type D:** Install renewables to reduce diesel operation.
- Type E:** Installation of an hybrid power system.



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Pros and Cons of Retrofitting

Advantages

- Reduced fuel consumption, fuel dependence
- Fewer generator operation hours
- Reduced operation & maintenance expenses
- Decreased pollution from generators and fuel
- Reduced need for personnel to control generators, if controls are added
- Automated performance monitoring, if controls are added

Disadvantages

- Capital cost of systems and controls
- Increased technical complexity of power plant operation and maintenance
- Increased start/stop cycles of generators



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Mt. Newall, Antarctica

- Science Foundation Station project
- Repeater and Seismic monitoring station
- Power System
 - 3.3 kW PV array
 - Diesel generator
 - HR3 wind turbine



Northern Power Systems



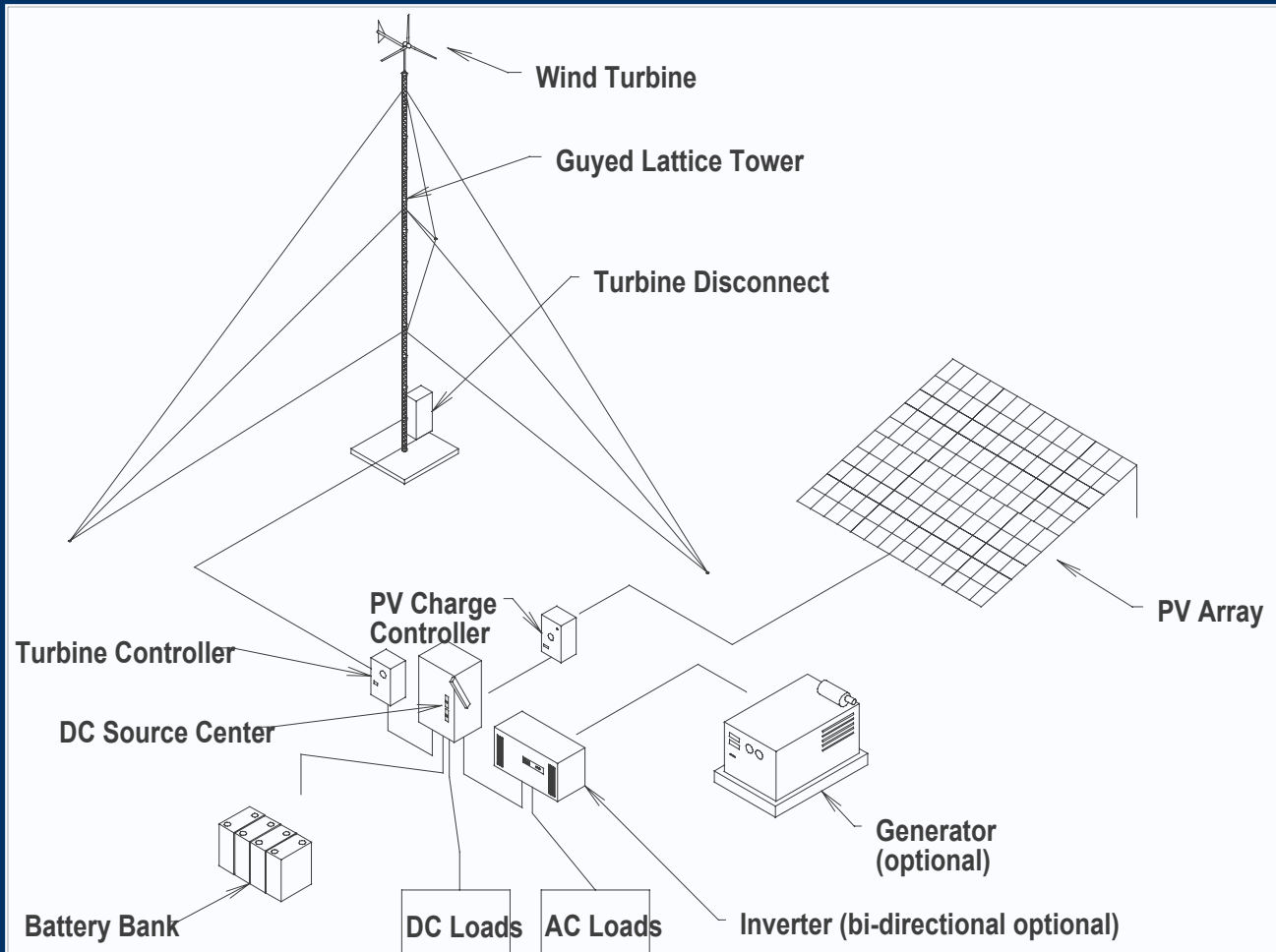
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Micro-Grid Power Systems

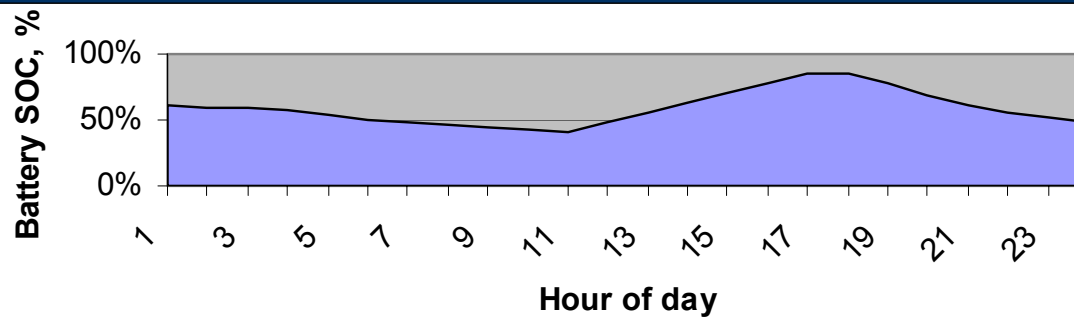
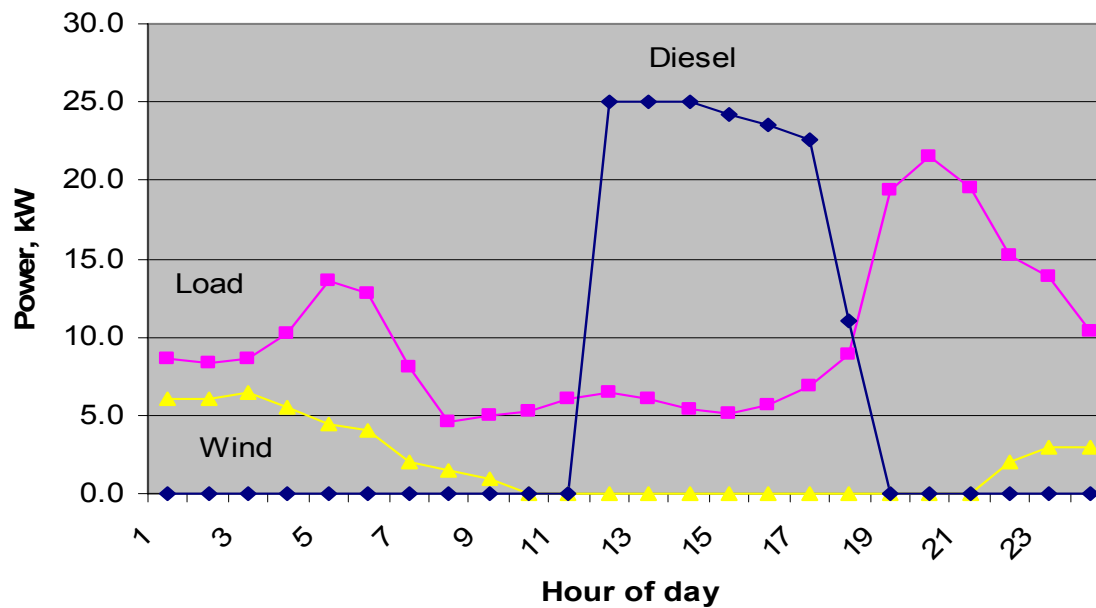
- Small systems with demands up to $\sim 100\text{kWh/day}$ load (15 kW peak load)
- Components of wind, PV, batteries and conventional generators
- Provide AC and potentially DC power
- Use of batteries to store renewable energy for use at night or low renewable times
- Generator used as backup power supply
- Mature market



Micro-grid System Architecture



Energy Flow for Small Hybrid



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Sunwize Power System

- **Whisper 3000 wind turbine**
- **1.8 kW PV (Siemens)**
- **5.8 kW diesel generator**
- **25.6kWh battery bank**
- **2-SW4048 4kW inverters**



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Village power system in Joanes, Brazil

Remote village the Island of Marajo

50kW Power System

- **PV array**
- **Four wind turbines**
- **Backup generator**



Northern Power Systems

Power system used to backup local grid



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San Juanico, Mexico

Remote fishing
community of 400
people with tourism

Power System

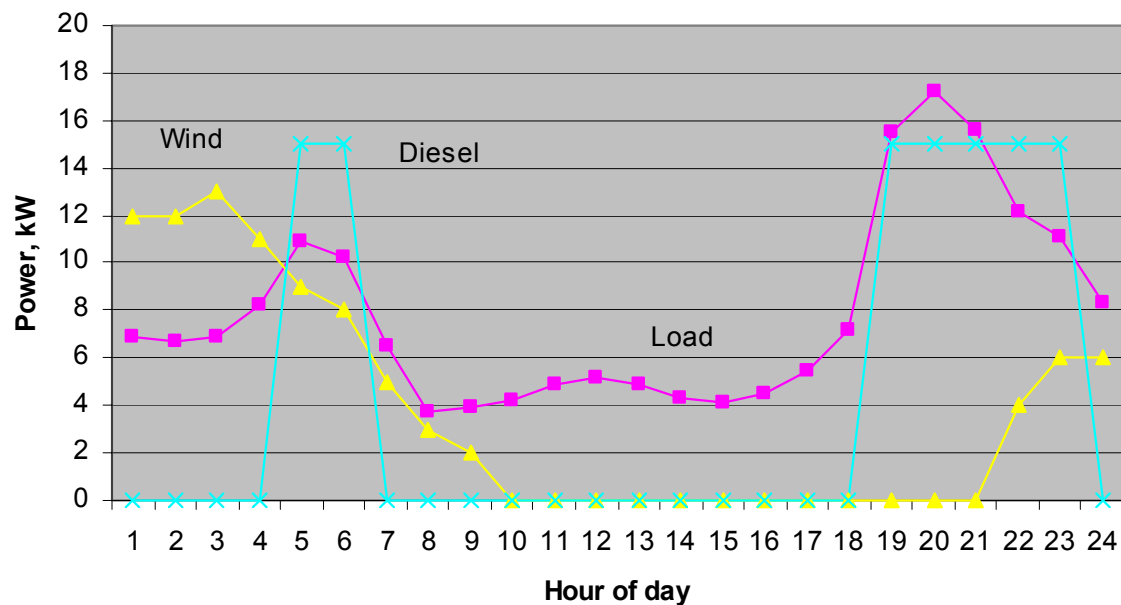
- 17 kW PV
- 70 kW wind
- 80 kW diesel generator



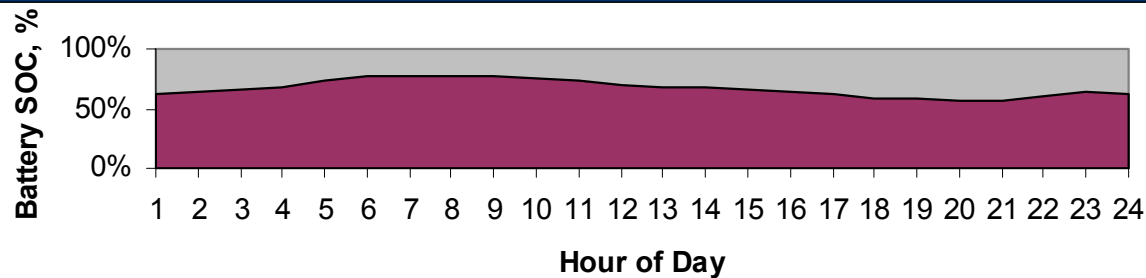
- 100 kW power converter/controller
- Advanced monitoring system



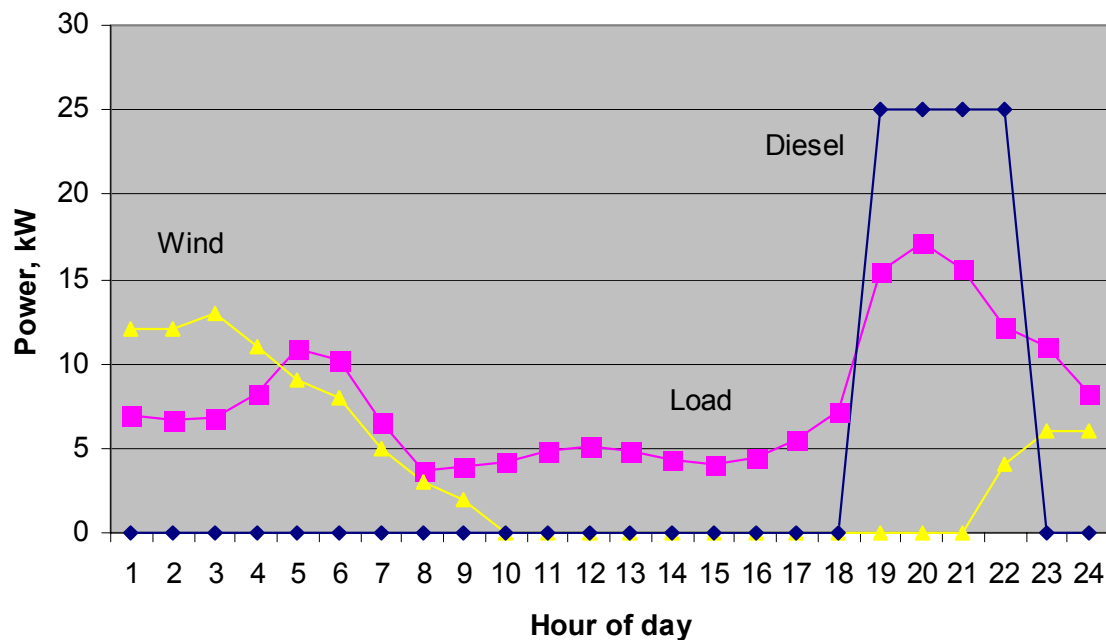
Parallel System - Smaller Diesel



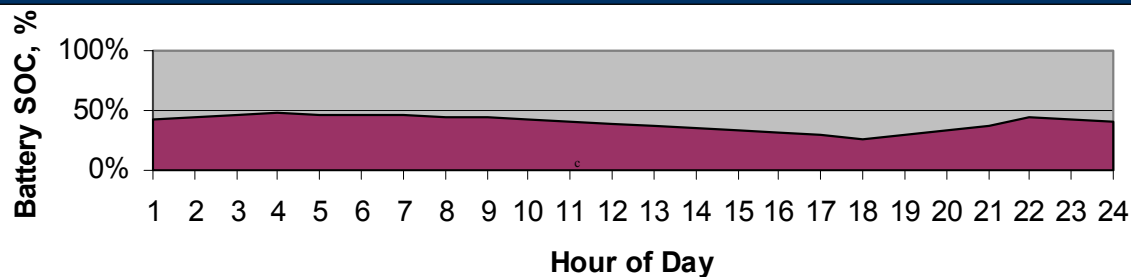
Both diesel and inverter needed to cover the maximum load. Both units run together.



Switched System - Larger Diesel



Both diesel and inverter sized to cover the complete load. Only one runs at a time.



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Mini-Grid Power Systems

- Larger systems with demands up to $\sim 700\text{kWh/day}$ load (100 kW peak load)
- Same components used as in Micro-Grids, just more of them and larger
- Use of batteries to store renewable energy for use at times of light loading
- Generator used to supply large loads
- Mature market though fewer examples
- Provide AC power



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Wind Penetration at SCI

- Average wind contribution 14% for the eleven month period since third turbine came on line
- Peak monthly wind contribution 22%
- Peak daily wind contribution 60%
- Peak instantaneous wind penetration estimated at 80%



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Ascension Island

- U.S. Air Force installation on British island in mid-Atlantic ocean.
- Pre-existing prime diesel generation with rotary interconnect to British 50 hertz system



Kotzebue, Alaska



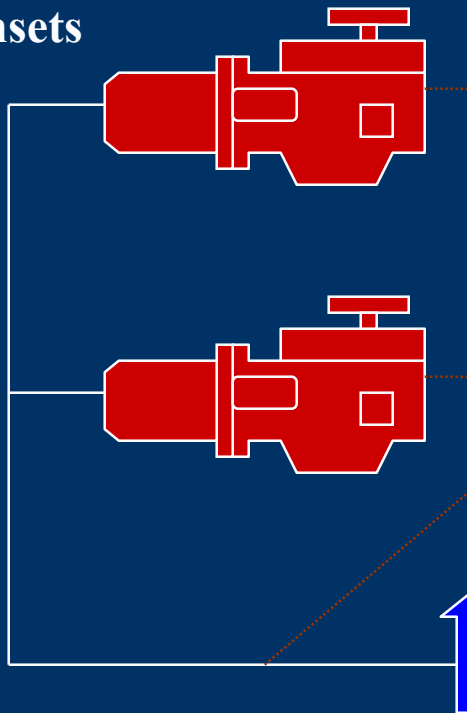
- 11 MW diesel power plant
- Fuel barged in annually
- 2MW average load: minimum load 700kW
- Peak wind penetration level ~ 50%
- Ten AOC 65 kW wind turbines
- Operating since early 1998
- No adverse effects of using wind
- Local utility plans expansion to 2-3 MW of wind turbine capacity



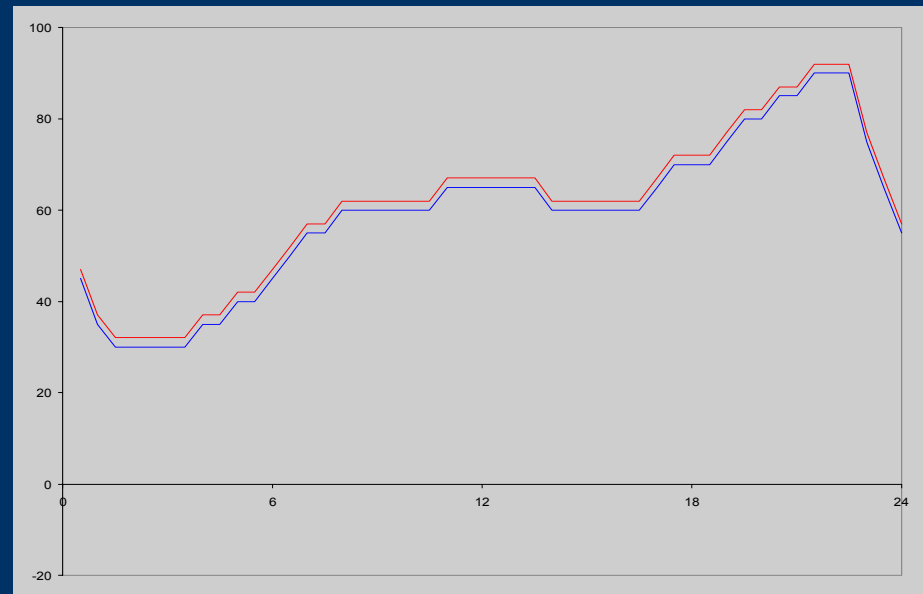
Diesel Only Power System

System Controller

Diesel Gensets



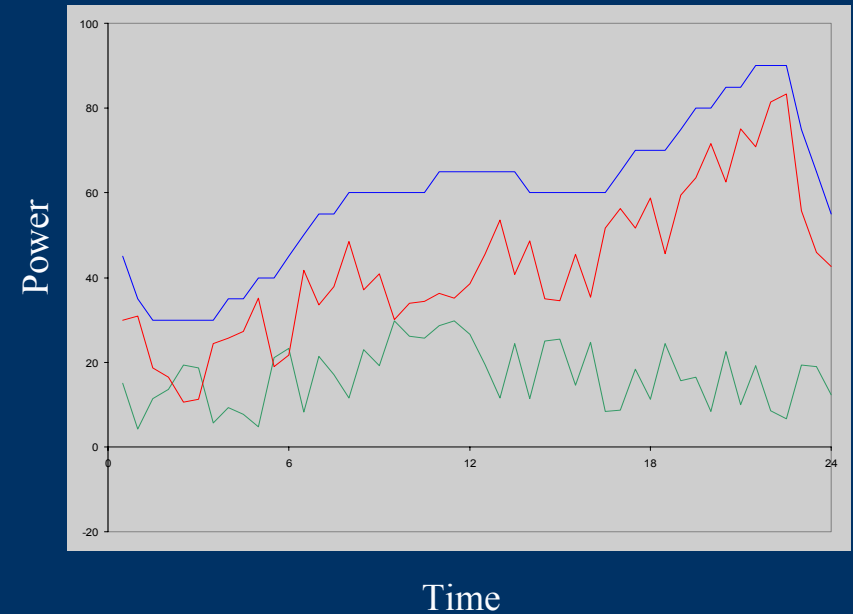
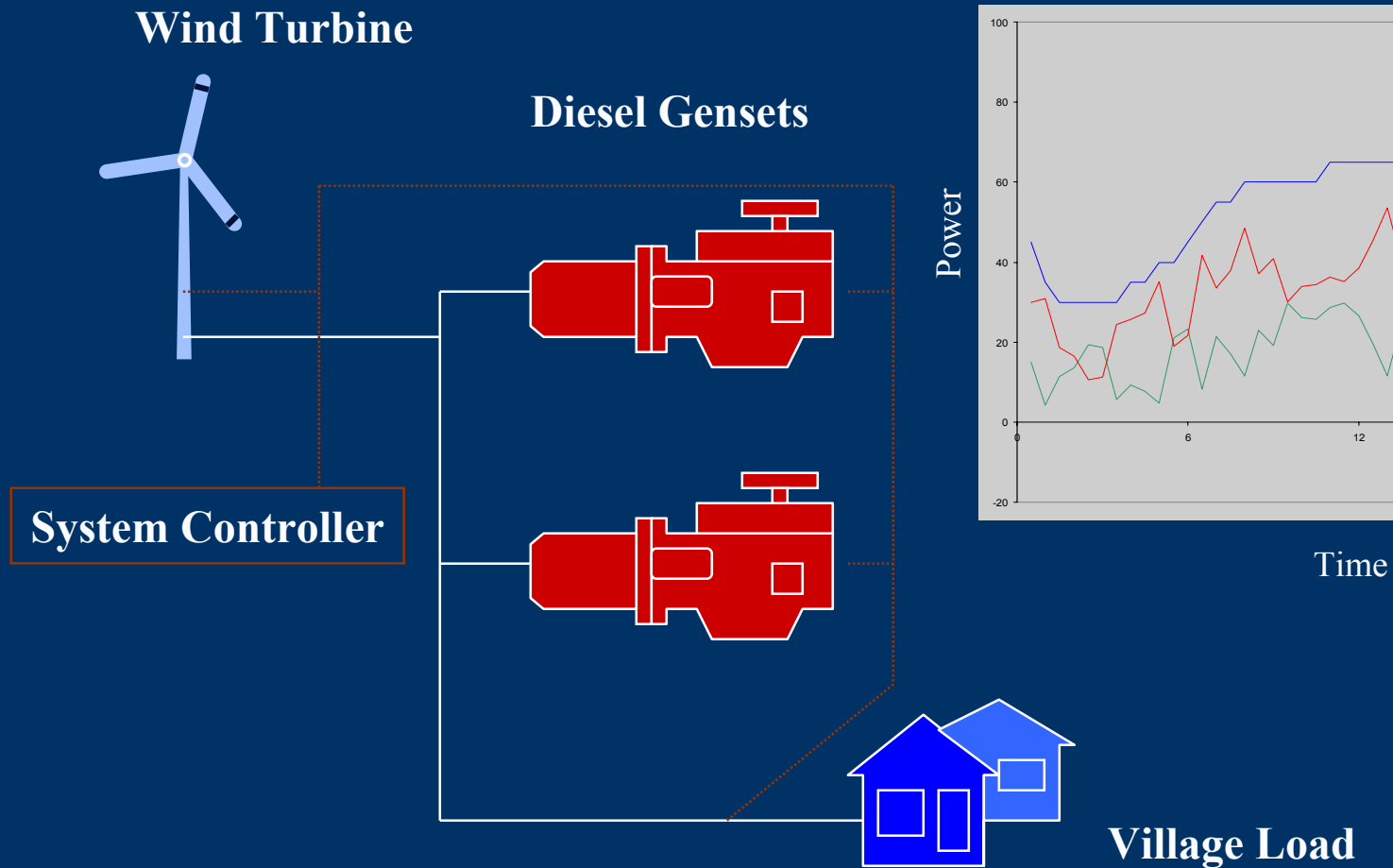
Power



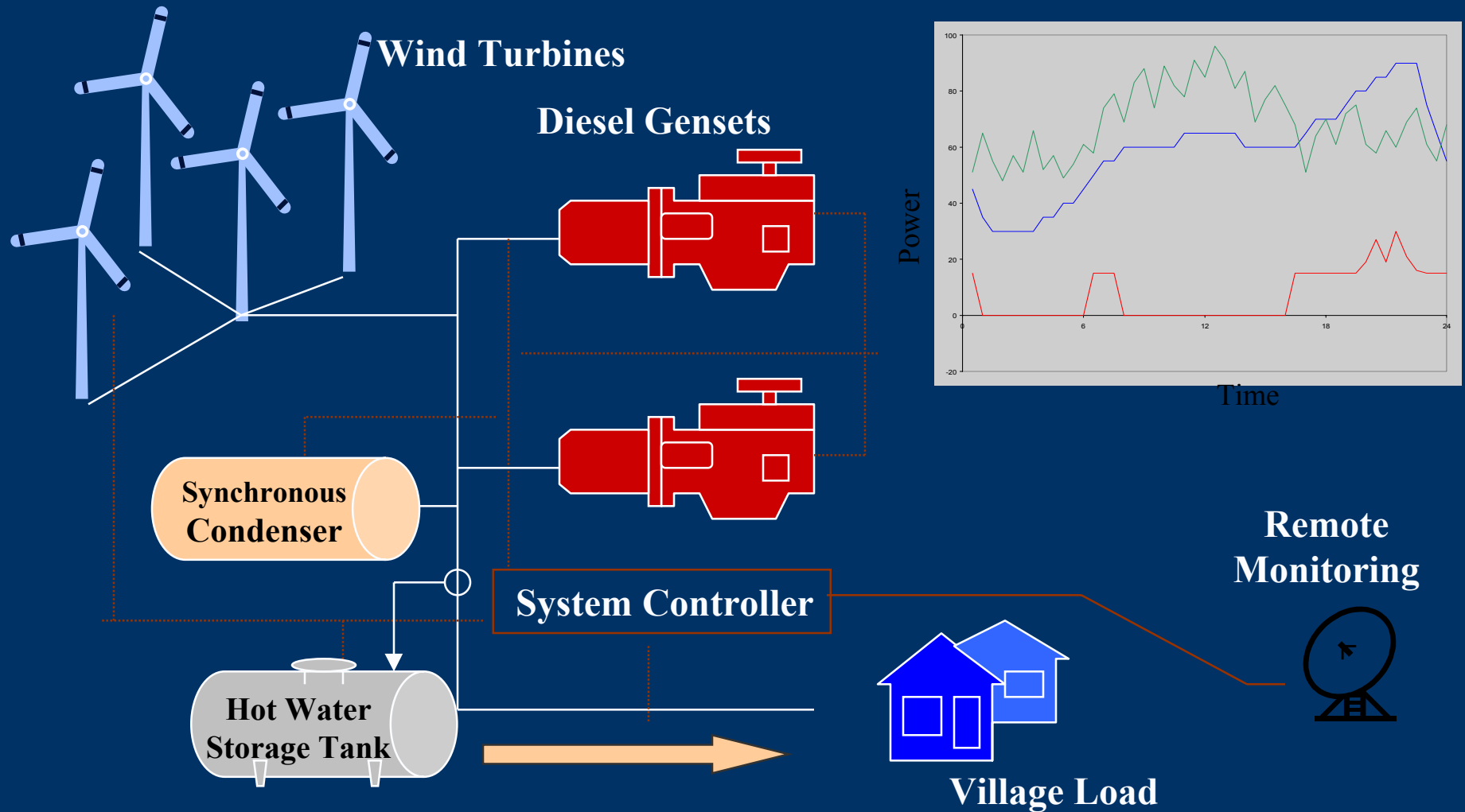
Time

Village Load

Low Penetration wind/diesel system



Advanced wind/diesel system



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St. Paul Alaska, USA

Island in the middle of the Bering Sea

Peak load of 160kW

Cost of Power, \pm \$0.21/kWh

Waste energy used for heating

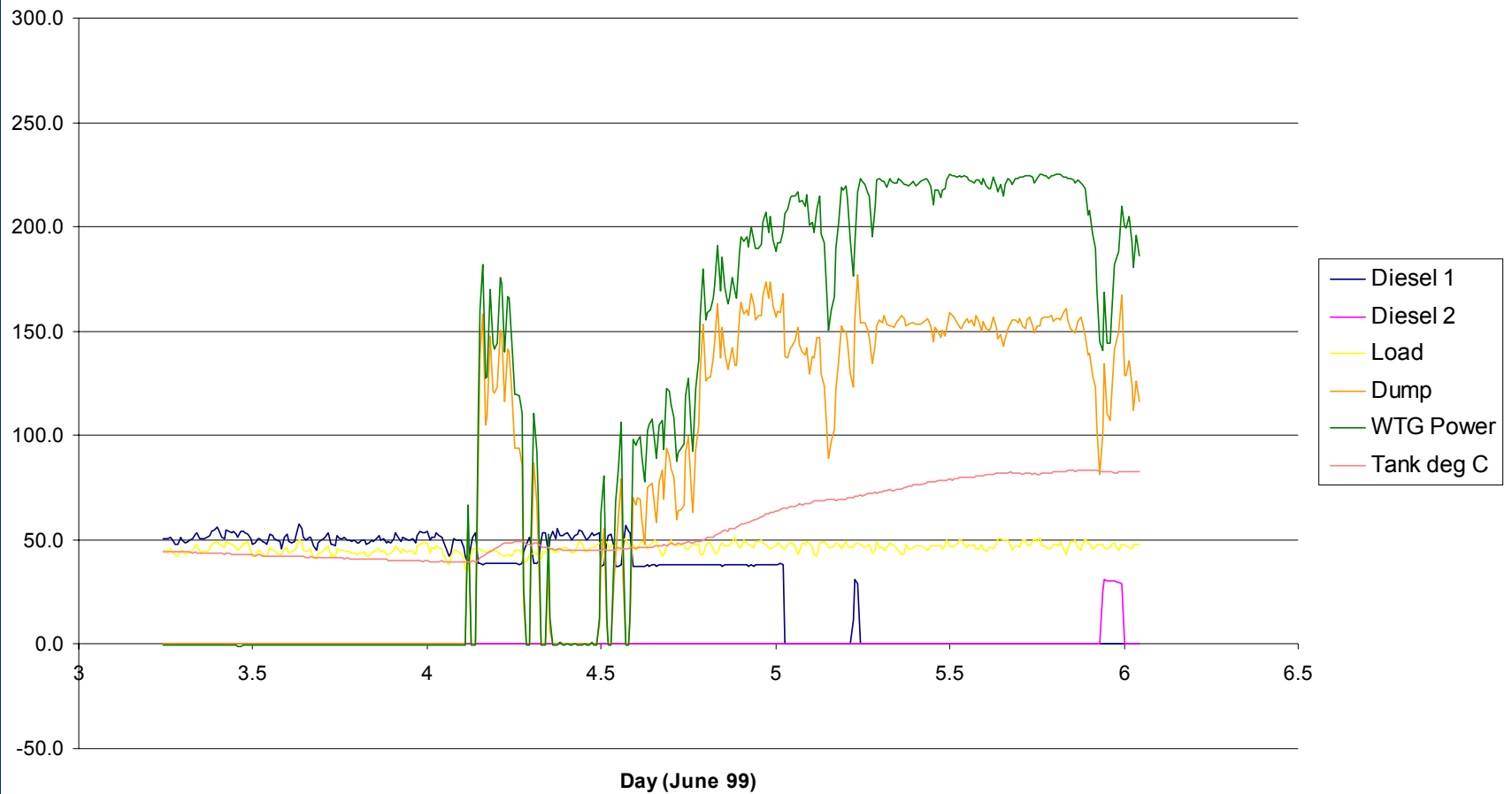


St. Paul Wind-Diesel Project Specifications

- System: **Stand Alone Utility: Combined Heat and Power**
- Configuration: **High Penetration/No Storage Wind-Diesel**
- Size: **500 kW**
- Application: **Public Power Supply, Providing Electricity and Space Heat to Industrial/Airport Facility**
- Location: **Pribilof Islands, Bering Sea**
- Peak Load: **160 kW (With Load Growth Planned)**
- Customer: **Tanadgusix Corporation (TDX)**
- Funding: **Commercial, lease based**
- Cost of Energy: **\pm \$.21/kWh (Current Diesel Grid Cost is \$.34/kWh)**



**10-Minute Data, NPS Hybrid Wind/Diesel Power System
TDX Corp., St. Paul Island, AK, USA**



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A High-Penetration Wind-Diesel System with Short Term Energy Storage in Wales, Alaska

- Location: NW Coast of Alaska, Bering Strait
- Population: ~160, mostly Inupiat Eskimo
- Average Wind Speed: > 8 m/s

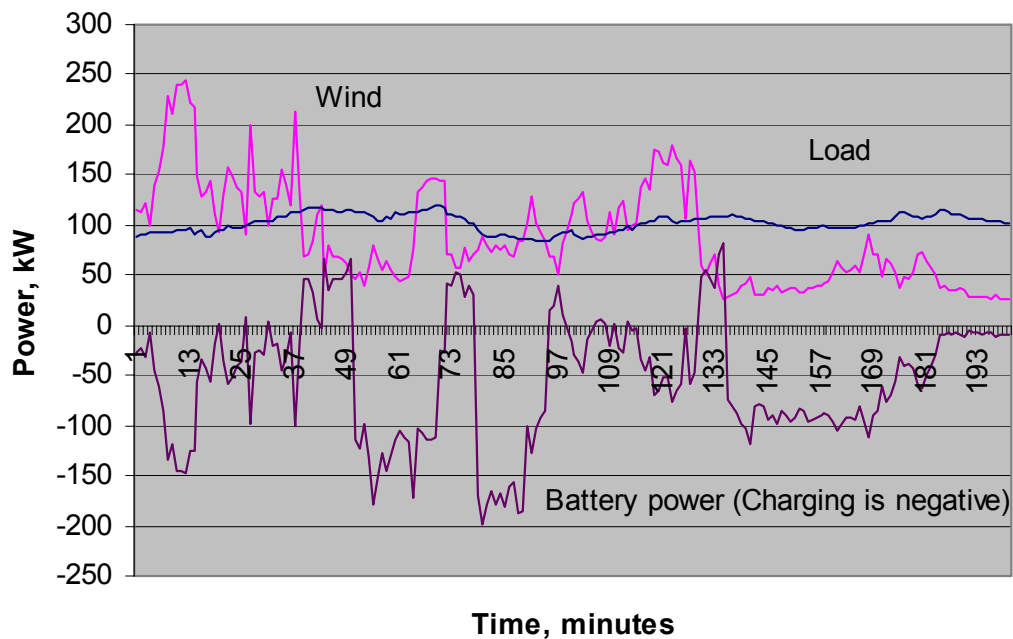


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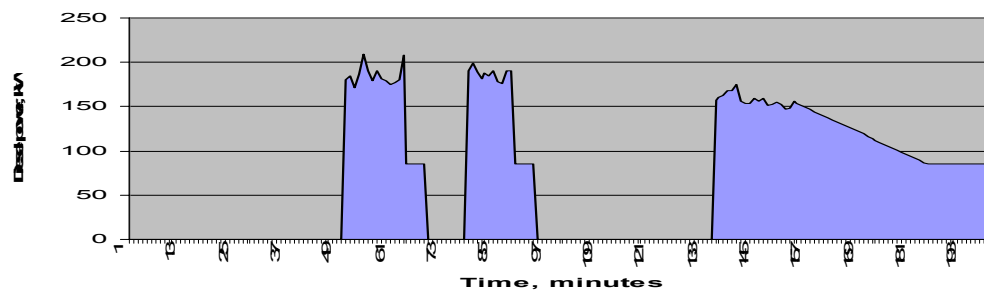
Village of Wales, Alaska



Wind/Diesel with short term storage



- Diesel used to provide power to system when the wind can not cover load.
- Battery used to fill short gaps in or to start diesel



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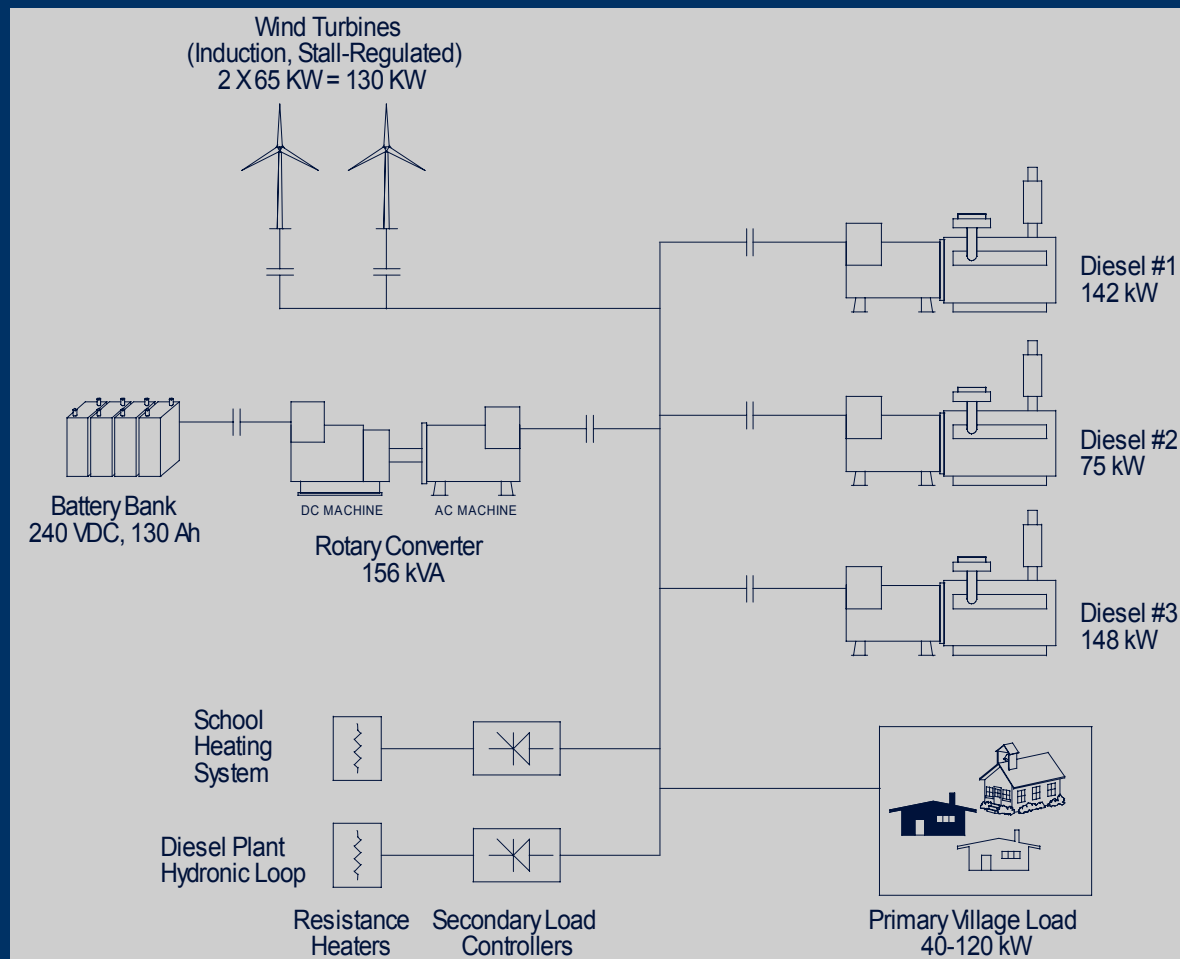
Wales, Alaska Wind Diesel System

High penetration system

- 80kW average load with 130kW of wind power
- Short term battery storage
- Resistive loads used for heating and hot water



Wales system Schematic



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NREL High Penetration Wind-Diesel System Design Objectives

- Substantial (>50%) reduction in diesel and heating fuel consumption.
- Productively use all available wind energy - no dumped energy.
- Minimize diesel run time through optimal use of energy storage.
- Employ a system architecture well-adapted to diesel retrofits.
- Employ a system architecture easily scalable from 100 kW to 5 MW.



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Atlantic Orient Wind Turbines Installed in Wales, Alaska



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Wales Rotary Converter and Battery



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NREL Diesel Retrofit Activities

- **Alaska**
- **Russia**
- **Argentina**
- **Chile**
- **Mexico**
- **Philippines**
- **China**
- **Indonesia**
- **United States**



Conclusions

- Lots of options for the configuration of hybrid systems - Depend on load, resource, and costs.
- Medium penetration wind-diesel systems are operating in various isolated locations around the world. Instantaneous wind penetration levels exceeding 50% of load are common.
- Several high penetration systems, with and without energy storage, have been successfully demonstrated.
- High penetration systems are capable of prolonged diesel -off operation.

